

IN THE SPECIFICATION:

Please amend paragraph [0051] as follows:

[0051] An exemplary stereolithographic apparatus 10 for fabricating features on semiconductor substrates 52, semiconductor devices 54 or associated components (e.g., lead frames, circuit boards, etc.) (not shown) or other fabrication substrates 50 is schematically depicted in FIG. 1. As shown, stereolithographic apparatus 10 includes a fabrication tank 100 and a material consolidation system 200, a machine vision system 300, a cleaning component 400, and a material reclamation system 500 that are associated with fabrication tank 100. The depicted stereolithographic apparatus 10 also includes a substrate handling system 600, such as a rotary feed system or linear feed system available from Genmark Automation-Inc., Inc., of Sunnyvale, California, for moving fabrication substrates 50 from one system of stereolithographic apparatus to another. Features of one or more of the foregoing systems may be associated with one or more controllers 700, or processing elements, such as computer processors or smaller groups of logic circuits, in such a way as to effect their operation in a desired manner.

Please amend paragraph [0055] as follows:

[0055] Photopolymers believed to be suitable for use with a stereolithography stereolithographic apparatus 10 according to the present invention include, without limitation, ACCURA® SI 40 HC and AR materials, ACCURA® SI 40 ND material, and CIBATOOL SL 5170, SL 5210, SL 5530, and SL 7510 resins. The ACCURA® materials are available from 3D Systems, Inc., of Valencia, California, while the CIBATOOL resins are available from Ciba Specialty Chemicals Company of Basel, Inc. of Bezel, Switzerland.

Please amend paragraph [0057] as follows:

[0057] A material consolidation system 200 is associated with fabrication tank 100 in such a way as to direct consolidating energy 220 into chamber 110 thereof, toward at least areas of surface 128 of volume 124 of unconsolidated material 126 within reservoir 120 that are

located over fabrication substrate 50. Consolidating energy 200-energy 220 may comprise, for example, electromagnetic radiation of a selected wavelength or a range of wavelengths, an electron beam, or other suitable energy for consolidating unconsolidated material 126. Material consolidation system 200 includes a source 210 of consolidating energy 220. If consolidating energy 220 is focused, source 210 or a location control element 212 associated therewith (e.g., a set of galvanometers, including one for x-axis movement and another for y-axis movement) may be configured to direct, or position, consolidating energy 220 toward a plurality of desired areas of surface 128. Alternatively, if consolidating energy 220 remains relatively unfocused, it may be directed generally toward surface 128 from a single, fixed location or from a plurality of different locations. In any event, operation of source 210, as well as movement thereof, if any, may be effected under the direction of controller 700.

Please amend paragraph [0059] as follows:

[0059] Optionally, as schematically depicted in FIG. 2, one or both of material consolidation system 200 (which may include a plurality of mirrors 214) and machine vision system 300 of a stereolithographic-apparatus 10-apparatus 10' may be oriented and configured to operate in association with a plurality of fabrication tanks 100. Of course, one or more controllers 700 would be useful for orchestrating the operation of material consolidation system 200, machine vision system 300, and substrate handling system 600 relative to a plurality of fabrication tanks 100.

Please amend paragraph [0068] as follows:

[0068] Control over the operation of actuation element 146' and, thus, over the movement of positioning element 140' and elevation of support element 132' may be provided by controller 700 or another processing element 105' (e.g., a processor or smaller collection of logic circuits), which may be dedicated for use with support system 130' or fabrication tank 100', in communication therewith, either as a part of fabrication tank 100' or, more generally, as a part of stereolithographic apparatus 10, 10' (FIGS. 1 and 2).

Please amend paragraph [0073] as follows:

[0073] Alternatively, as shown in FIG. 3E, a volume adjustment element 154" may include one or more apertures or other openings 102 in a side wall 101 of fabrication tank 100' that have lower edges 103 that are positioned at an elevation within fabrication tank 100' at which surface 128 of volume 124 of unconsolidated material 126 is to be maintained. In addition, surface level control element 154" includes one or more receptacles 104 that communicate with openings 102 to receive overflowing unconsolidated material 126 as support element 132'~~an-a-~~and a substrate or other workpiece thereon, as well as any stereolithographically fabricated objects, are lowered into fabrication tank 100' and displace unconsolidated material 126 therein. A pumping system or other material recycling element 105 may communicate with each receptacle 104 in such a way as to return overflowed unconsolidated material 126 to tank 100' as support element 132' is raised to facilitate stereolithographic fabrication of one or more other objects.

Please amend paragraph [0076] as follows:

[0076] As shown, reservoir 120" may be configured to contain a substantially constant volume 124 of material, including unconsolidated material 126 and, if stereolithographic processes have been initiated, consolidated material 126' (FIG. 14). Accordingly, reservoir 120" may include a surface level control element-150', 150", such as that described above in reference to FIGs. 3, 3C, and 3D.

Please amend paragraph [0080] as follows:

[0080] Material reclamation zone 170" and cleaning zone 180" may each be provided with a receptacle 172", 182", respectively, that extends substantially around the periphery of an inner boundary or wall 114" of reservoir 120". Receptacles 172" and 182" are each positioned at approximately the same elevations within reservoir 120" that support element-132"~~"~~132" will be located when positioned within reclamation zone 170" and cleaning zone 180" thereof,

respectively. Accordingly, as excess unconsolidated material 126 and/or cleaning agents 127 are removed, by spinning, from each fabrication substrate 50 that is carried by support element 132", receptacle 172", 182" will receive substantially all of the excess unconsolidated material 126 or cleaning agents 127 that are removed therefrom.

Please amend paragraph [0086] as follows:

[0086] Also, in order to secure fabrication substrate 50 in place relative to support surface 134", retention system 190 may include one or more pressure ports 196, which are configured to communicate with a pressure source 197 (e.g., a vacuum or an air compressor). As support element 132" is configured to be rotated, each pressure port 196 may be fitted with a valve 199, which seals that pressure port 196 when pressure source 197 is not in communication therewith. Of course, such valves 199 are not necessary when support element 132" does not rotate, as in fabrication tank 100'. As a negative pressure is applied through the one or more pressure ports 196 to a bottom surface 51 of fabrication substrate 50, the negative pressure pulls fabrication substrate 50 against sealing element 198, sealing bottom surface 51 against sealing element 198. In addition to securing fabrication substrate 50 over support surface 134" and possibly providing a cushion for fabrication substrate 50, as noted previously, sealing element 198 may prevent unconsolidated-material material 126 from contacting bottom surface 51 and support surface 134". Operation of pressure source 197 and, if necessary, communication thereof with pressure ports 196 may be under control of controller 700, processing element 105', or another processing element that is dedicated for use with retention system 190.

Please amend paragraph [0087] as follows:

[0087] FIGs. 4C and 4D illustrate a variation of retention system 190', which is useful with support element 132" of fabrication tank 100". Retention system 190' includes one or more ejection elements 196'. Ejection elements 196' are useful for removing fabrication substrate 50 from receptacle 192, as well as for breaking a seal caused by the presence of a negative pressure beneath fabrication substrate 50, which is applied against at least a portion of bottom surface 51

thereof. Operation of ejection elements 196' may be controlled by way of a controller 700 in communication therewith. By way of example only, each ejection element 196' may comprise a mechanical piston that may be recessed within support surface 134" to facilitate placement of a fabrication substrate 50 thereon or raised by an actuation element 197' (e.g., a pneumatic, hydraulic, or mechanical actuation element) to protrude from support surface 134" and eject a fabrication substrate 50 from ~~recess~~ receptacle 192 and raise fabrication substrate 50 to facilitating grasping thereof by substrate handling system 600. In this example, it is actuation element 197' that communicates with controller 700, processing element 105', or another processing element and that operates in accordance with instructive signals, or carrier waves, from controller 700, processing element 105', or the other processing element.

Please amend paragraph [0089] as follows:

[0089] Optionally, pressure ports 196 may be configured and the output of pressure source 197 modulated so as to create a circulating airflow beneath bottom surface 51 as positive pressure is forced therethrough, causing fabrication substrate 50 to be lifted off of support surface 134" in such a way as to hover thereover in accordance with Bernoulli's Law. Such an ejection element 196' is, therefore, useful for facilitating the grasping of fabrication substrate 50 by a substrate handling system 600 (FIGs. 1 and 2) of ~~stereolithography~~ stereolithographic apparatus 10, 10', as well as to remove any unconsolidated material 126 from support surface 134".

Please amend paragraph [0094] as follows:

[0094] Optionally, with returned reference to FIG. 4, fabrication tank 100" may include a bubble elimination system 165', such as that described in reference to FIG. 3. Alternatively, stereolithographic fabrication tanks 100, such as those that have chambers 110 with relatively small volumes (e.g., which are sufficient to contain only a single semiconductor substrate 52), may include bubble elimination systems that create a negative pressure, or vacuum, within the chambers thereof. Such a bubble elimination system may, for example, include one or more

sealing elements, which substantially seal chamber 110 of stereolithographic apparatus 10 (FIG. 1)-chamber 110, as well as a negative pressure source that communicates at least with chamber 110 so as to facilitate the creation of a negative pressure therein.

Please amend paragraph [0096] as follows:

[0096] Of course, operation of dispenser 120" may be controlled by controller 700 or by a processing element 105" (e.g., a ~~processor~~ processor or smaller group of logic circuits) that is associated with fabrication tank 100".

Please amend paragraph [00104] as follows:

[00104] A source 210" of consolidating energy 220" may remain in a fixed position as consolidating energy 220" is introduced into chamber 110 or source 210" may be moved, such as by an actuation system 217" therefor. By way of example only, such an actuation system 217" may comprise an X-Y plotter of a known type, which may operate and, thus, move source 210" under the direction of signals, or carrier waves, that have been transmitted by controller 700 or by a processing element 205" (e.g., a processor or smaller group of logic circuits) that controls operation of machine consolidation system 200". Operation of source 210" may be under control of ~~controller~~ controller 700 or processing element 205".

Please amend paragraph [00108] as follows:

[00108] In FIG. 8, a scanning embodiment of machine vision system 300', or one which is configured to move relative to a chamber 110 of a fabrication tank 100 (FIGs. 1 and 2) with which it is used, is depicted. Machine vision system 300' includes a camera 310' which may be carried and moved over a fabrication substrate 50 by a scan element 312'. Scan element 312' positions camera 310' in close proximity to (e.g., inches from) surface 128 (FIG. 1) of volume 124 of unconsolidated material 126 (FIG. 1) so as to enable camera 310' to view minute features on a fabrication substrate 50 (e.g., bond pads, fuses, or other circuit elements of a semiconductor device)-~~that is~~-that are located at or near surface 128. Upon viewing fabrication

substrate 50, camera 310' communicates information about the precise locations of such features (e.g., with an accuracy of up to about ± 0.1 mil (*i.e.*, 0.0001 inch)) to a computer 320' of machine vision system 300'.

Please amend paragraph [00110] as follows:

[00110] Suitable electronic componentry, as required for adapting or converting the signals, or carrier waves, that are output by camera 310', may be incorporated in a board 322' installed in a computer 320'. Such electronic componentry may include one or more processors 324', other groups of logic circuits, or other processing or control elements that have been dedicated for use in conjunction with camera 310'. At least one-processing-element-processor 324', which may include a processor 324', processor, another, smaller group of logic circuits, or other control element that has been dedicated for use in conjunction with camera 310', is programmed, as known in the art, to process signals that represent images that have been "viewed" by camera 310' and respond to such signals.

Please amend paragraph [00111] as follows:

[00111] A self-contained machine vision system available from a commercial vendor of such equipment may be employed as machine vision system 300'. Examples of such machine vision systems and their various features are described, without limitation, in U.S. Patents 4,526,646; 4,543,659; 4,736,437; 4,899,921; 5,059,559; 5,113,565; 5,145,099; 5,238,174; 5,463,227; 5,288,698; 5,471,310; 5,506,684; 5,516,023; 5,516,026; and 5,644,245. The disclosure of each of the immediately foregoing patents is hereby incorporated herein in its entirety by this reference. Such systems are available, for example, from Cognex Corporation of Natick, Massachusetts. As an example, and not to limit the scope of the present invention, the apparatus of the Cognex BGA-Inspection Package™-INSPECTION PACKAGE™ or the SMD Placement Guidance Package™-PLACEMENT GUIDANCE PACKAGE™ may be adapted for use in a stereolithographic apparatus 10 (FIG. 1) that incorporates teachings of the present invention, although it is currently believed that the MVS-8000™ product family and the

Checkpoint® product line, the latter employed in combination with Cognex PatMax™ PATMAX™ software, may be especially suitable for use in the present invention.

Please amend paragraph [00112] as follows:

[00112] A response by computer 320' may be in the form of instructions regarding the operation of a material consolidation system 200 (FIGs. 1 and 2), such as the selectively consolidating material consolidation system 200' shown in FIG. 6. These instructions may be embodied as signals, or carrier waves. By way of example only, such responsive instructions may be communicated to controller 700 of stereolithographic apparatus 10, 10' (FIGs. 1 and 2, respectively) or directly to a processing element 205' (FIG. 6), such as a processor or group of processors, associated with a material consolidation system 200 (FIGs. 1 and 2) (e.g., material consolidation system 200' shown in FIG. 6) with which machine vision system 300' is used. Controller 700 or ~~e~~ontrol-processing element 205' may, in turn, cause material consolidation system 200' to operate in such a way as to effect the stereolithographic fabrication of one or more objects on fabrication substrate 50 precisely at the intended locations thereof.

Please amend paragraph [00127] as follows:

[00127] Like initial material removal component 410', secondary material removal component 430' of cleaning component 400' includes support system 130" of fabrication tank 100". In addition, secondary material removal component 430' includes cleaning zone 180" and receptacle-~~182~~ 182" thereof of chamber 110". Support system 130" and, in particular, actuation element 146" or rotation element 148" thereof, is configured to accelerate rotation of a fabrication substrate 50 carried thereby to a sufficiently high speed (e.g., about 50 to about 6,000 rpm) so that any cleaning agents 127 or unconsolidated material 126 thereon will be forced therefrom along substantially the same plane as that within which fabrication substrate 50 is located, into receptacle 172", and prevented from falling into reservoir 120".

Please amend paragraph [00131] as follows:

[00131] Material removal component 410", which is positioned external to fabrication tank 100", may comprise one or more removal heads 412", through which either a negative pressure (e.g., a vacuum) or a positive pressure (e.g., about 30 psi (which is typically not sufficient to puncture the skin of an operator of stereolithographic apparatus 10, 10') or higher pressures may be used and delivered by a so-called "air-knife", knife," such as that manufactured by Secomak Ltd. of Middlesex, United Kingdom, at a sufficient velocity to overcome the adhesion of unconsolidated material 126 from fabrication substrate 50 and, thus, remove unconsolidated material 126 from fabrication substrate 50) may be applied to a fabrication substrate 50. Each removal head 412" may be supported by a positioning element 414", such as a robotic arm. Positioning element 414" places removal head 412" in sufficient proximity to one or more surfaces of a fabrication substrate 50 so that a negative pressure (e.g., a vacuum) or positive pressure applied to fabrication substrate 50 by removal head 412" may respectively draw any excess unconsolidated material 126 on fabrication substrate 50 into removal head 412" or blow any excess unconsolidated material 126 from fabrication substrate 50. Alternatively, support element 430" may be transported so as to move fabrication substrate 50 in proximity to one or more removal heads 412". Material removal component 410" may be used in combination with a bulk removal process, such as tipping or inverting a fabrication substrate 50 to permit unconsolidated material 126 to flow therefrom.

Please amend paragraph [00134] as follows:

[00134] Another embodiment of cleaning component 400"" that may be used in a stereolithography-stereolithographic apparatus 10, 10' (FIGs. 1 and 2, respectively) according to the present invention is shown in FIG. 11. Cleaning component 400"" includes a tank 440"" which is at least partially filled with one or more cleaning agents 127 and within which one or more fabrication substrates 50 may be introduced, such as by the illustrated wafer boat 450"". Additionally, cleaning component 400"" may include an agitation system 460"", which facilitates the removal of residual unconsolidated ~~material~~-material 126 from fabrication substrates 50. By

way of example only, agitation system 460[”] may include a vertical agitation system, which repeatedly moves a support 452[”] upon which wafer boat 450[”] is carried up and down.

Please amend paragraph [00142] as follows:

[00142] The position at which selectively consolidating energy impinges upon surface 128 may, by way of example only, be calibrated by selectively consolidating unconsolidated material 126 at one or more calibration locations, each of which is referred to herein as a “reference pixel” 750, on surface 128. Next, each reference pixel 750 is “viewed” by machine vision system 300 to locate the same relative to a reference grid (not shown), which may be stored in memory of either computer 320’ (FIG. 8) or controller 700 (FIG. 1). The location at which each reference pixel 750 actually appears is then compared with the anticipated location 750’ for reference pixel 750. Material consolidation system 200, the reference grid, or a combination of both may then be adjusted, as known in the art, to compensate for any difference between anticipated location 750’ and the actual location of reference pixel 750.

Please amend paragraph [00149] as follows:

[00149] Before fabrication of a first layer 22a of an object 20 is commenced, the operational parameters for stereolithographic apparatus 10, 10’ may be set to adjust the size (diameter if circular) of selectively consolidating energy (e.g., laser beam 220’ shown in FIG. 6), if such is used to at least partially consolidate unconsolidated material 126.

Please amend paragraph [00153] as follows:

[00153] Laser 210’ (FIG. 6) may then be activated so laser beam 220’ will scan surface 128 of volume 124 of unconsolidated material 126 so as to at least partially consolidate (e.g., polymerize to an at least semisolid state) the same, thereby defining boundaries of a layer 22 of object 20 and filling in solid portions thereof. Support system 130, 130’, 130”, 130” may then be lowered to lower fabrication substrate 50 a distance that is substantially equal to the desired thickness of the next layer 22 of object 20 to be fabricated thereover, and the selective

consolidation process repeated, as often as necessary, layer by layer, until each object 20 is completed. Of course, the number of layers 22 that are required to form object 20 may depend upon the height of object 20 and the desired thickness for each layer 22 thereof. Different layers 22 of a stereolithographically fabricated object 20 may have different thicknesses.